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DEVELOPMENT OBJECTIVES

PRECISE MEASUREMENT STUDY

1. INTRODUCTION

These objectives describe the background, concept and requirements of a Government-sponsored research and development program in precise measurement (or precision mensuration) as it relates to the imagery exploitation process.

2. BACKGROUND

Methods and instruments to obtain measurements of imagery on reconnaissance type aerial photography have developed in a somewhat piecemeal manner since World War II. Present practices range from simple comparison measurements using tube magnifiers to complex measurements on comparators on-line to computers. The degree of accuracy claimed in obtaining imagery measurements by these methods is questionable and has come under continuous fire.

A lack of knowledge concerning specific requirements, accuracies, and capabilities in the acquisition - exploitation - utilization, inter relationship is handicapping the mensuration effort.

The ability of the photogrammetrist and interpreter to measure is limited by their physical environment and functional parameters such as the imagery he can see, the controls he can manipulate, and the item to be measured. These conditions, when combined with the design features of a measuring instrument result in the ultimate precision of the mensuration process.

3. CONCEPT

This program is directed toward: the investigation and establishment of the accuracy requirements of the Users by category; the analysis and determination of the qualitative and quantitative parameters of the various acquisition systems; and the evaluation and proposal of procedures and instrumentation necessary to achieve the precision required in the exploitation processes.

It should be emphasized that this study is not directed toward developing acquisition systems, but toward the use of information and data on cameras and films and their inter-relationship in order to produce precise measurements to fulfill the User's requirements.

4. GENERAL DESCRIPTION

The objective of this program is to study the User's requirements, the acquisition system's capabilities, and the precision mensuration capability of the exploitation system as a single, integrated package. The desired accuracy, the quantity, the time required, and the various categories of measurements required by the User will be evaluated in relation to the resolution, the contract, the film stability, and the geometry of present and proposed acquisition systems. Further, present measuring instruments will be evaluated, recommendations made, and specifications generated to provide for future requirements.

The goal of this program is to obtain reliable information and recommendations as to improving and developing measurement systems commensurate with proposed acquisition systems and User's requirements.

This goal will be accomplished through: an extensive literature search, a thorough investigation of requirements, a scientific evaluation of experimental and operational data, the creation of analytical and experimental models, and by a limited amount of breadboarding.

5. DETAILED OBJECTIVES

5.1. Review of User's Requirements

5.1.1. Prepare a list of: Users (by type), the frequency of the requests, the number and type of measurements requested, and the response time required.

5.1.2. Visit the User's facilities, establish their requirements by desired accuracy, the use of the measurements (e.g., R&D, model makers, analyst, etc.) and determine their projected needs.

5.2. Study of Acquisition Systems as Related to Mensuration

5.2.1. Review present Operation Systems to determine:

5.2.1.1. Accuracy of positioning system and attitude determination methods.

5.2.1.2. Geometric strength and types of format (e.g., frame, pan, strip).

5.2.1.3. Quality of optics.

5.2.1.4. Film and Emulsion. Stability, MTF, Resolution.

5.2.1.5. Atmospheric Effects

5.2.1.6. Thermal and inertial effects

5.2.2. Review Proposed Systems to Determine:

5.2.2.1. Theoretical and computed accuracy and reliability of positioning.

5.2.2.2. Programmed and proposed cameras.

5.2.2.3. Proposed film and emulsion types. Thin Base, UTB, Color.

5.3. Obtain and review inputs from other Government sponsored research and study.

5.3.1. Typical research programs that are currently in progress and from which information will be available are as follows:

5.3.1.1. Image Analysis

5.3.1.2. Human Fa ctors

5.3.1.3. Precision Stereo Comparator

5.3.1.4. Automatic Stereo Scanning

5.3.2. The selected contractor will in turn be expected to supply data and information to the contractors on the above listed programs.

5.4. Perform a detailed evaluation and analysis based upon the present and proposed acquisition systems and the User's requirements to establish the necessary accuracy required by the various categories that use the measurements in relation to the quality of imagery obtained by the camera/film combination.

5.5. Evaluate Operational Procedures

5.5.1. Evaluate the various mensuration procedures that are in use.

5.5.2. Evaluate the accuracy of input parameters such as:

5.5.2.1. Accuracy of positioning system and time velocity readout.

5.5.2.2. Accuracy of data reduction. Stellar readout procedures.

5.5.3. Reproduction type film (Dupe Pos.) Stability, Resolution, MTF, Proposed improved film?

5.6. Evaluate Film Base Stability as Related to:

5.6.1. Processing of original and changes caused by it.

5.6.2. Reproduction methods and comparison of duplicate positives with original.

5.6.3. Chip vs. roll storage for dimensional changes.

5.7. Review Present Mensuration Equipment to Determine Objectively:

5.7.1. The accuracy and time to accomplish various mensuration tasks.

5.7.1.1. Vectorial

5.7.1.2. One stage, two axis

5.7.1.3. Stereo viewing but measuring with one stage, vice two axis.

5.7.1.4. Stereo, two stage, four axis.

5.7.2. The effect of viewing systems upon the mensuration process.

5.7.2.1. Anamorphic effects

5.7.2.2. Magnification, resolution and other factors affection mensuration.

5.7.2.3. Field of view

5.7.2.4. Contrast

5.7.3. Study film hold down systems and determine their effects upon measurements.

5.7.4. Viewing Illumination

5.7.4.1. General vs. high intensity spot

5.7.4.2. Effects of the amount of light at the eye, the color temperature, etc. on the accuracy of measuring and pointing.

5.8. Experiment and Test to Determine:

5.8.1. Dimensional changes in the various films caused by varying temperature, humidity, light intensity, methods of cooling film and various film hold down or clamping methods.

5.8.2. Measuring precision

5.8.2.1. Monocular

5.8.2.2. Binocular, single stage

5.8.2.3. Stereoview, one stage measuring

5.8.2.4. Stereo measuring

5.8.3. Type of reticle

5.8.3.1. Point Light Source

5.8.3.2. Perfect Black Dot

5.8.3.3. Cross and others

5.8.4. Types of encoders or standards

5.8.4.1. Scaled Instruments

5.8.4.2. Verniers and Micrometers

5.8.4.3. Standards, comparators, calibration

5.8.4.4. Optical flats

5.9. Develop Analytical Models for Film Coefficients

5.9.1. Analytical Model for a computer. Develop a math model that can provide the corrections required to get accurate mensuration.

a. Film Type and Characteristics

b. Comparator to be use Light Source, etf)

c. Processing Changes

d. Acquisition Changes

5.9.2. Effects of high intensity light source on small areas of film and methods of correcting for it.

5.10 Generate Specifications that should be incorporated into immediate and future mensuration equipment.

5.11. Prepare Cost vs. Performance Curves for the mensuration tasks, instruments, the degree of precision, and the camera/film taking system.

6. TECHNICAL REQUIREMENTS

It is realized that the complexity and emphasis ~~of what~~ will vary and be shifted with the findings of the study. The objectives listed in Section 5 are very broad and within these areas the contractor will perform the following:

6.1. Provide consultation to the Government in the precise measurement field.

6.2. Have an expert awareness of past and present research in this field so as to prevent duplication.

6.3. Have the capabilities to undertake studies to determine the most desirable mensuration procedure for a task.

6.4. Be capable of undertaking practical experimentation as well as the theoretical approach on imagery measuring problems.

6.5. Be capable of determining the dynamic range capabilities and limitations of possible systems utilizing film inputs.

6.6. Conduct studies to determine the sub systems that require a major research effort.

6.7. Create analytical models that will allow various parameters to be manipulated in relation to each other (e.g. temperature, vacuum, etc.).

6.8. Determine weak link.

7. AREAS OF INVESTIGATION

It is expected that the contractor will be able to obtain some of the information from technical publications and classified reports as well as from other prime contractors. It is anticipated that the majority of the information will have to be obtained through the contractor's investigations.

The contractor is not expected to be expert in all phases of the work since such a broad area is covered. Liberal use of consultants and sub contractors is allowed but the prime contractor will be held responsible for the quality of the work and for insuring the coordination and scheduling of the total program.

The program will cover all the areas mentioned in this section (7). The contractor may suggest any other areas that he deems important.

7.1. Acquisition System Errors

7.1.1. Taking camera

7.1.1.1. Type of camera configuration - frame, pan, strip.

7.1.1.2. Calibration of cameras - residual coordinate errors in past systems.

7.1.1.3. The flatness or planenss of the film in the camera during the taking period.

7.1.1.4. The temperature and humidity within the camera.

7.1.2. Original film in taking camera

7.1.2.1. Type of film and base thickness - thin, UTB, color.

7.1.2.2. Amount of tension on transport system.

7.1.2.3. Thickness variation in the film.

7.1.2.4. Effects and reaction of emulsion.

7.1.3. Camera lens/film relationship

7.1.4. Aircraft/camera attitude determination methods.

7.1.5. Atmospheric refraction effect

7.2. Processing Errors

7.2.1. Original Film - Stability of thin film, UTB and the errors introduced by manipulation of the control parameters.

7.2.2. Duplicate material - Reproduction and processing changes and errors.

7.3. Measuring Errors

7.3.1. Comparator

7.3.1.1. Type - Stereo, Mono

7.3.1.2. Measuring engine accuracy

7.3.1.3. Viewing magnification

7.3.1.4. Illumination System

7.3.1.5. Method of film hold down and its affect

7.3.1.6. Effects of correlation and anamorphs

7.3.1.7. Accuracy of pointing with various reticles

7.3.1.8. Apparent size of reticle (dot) in the image plane in relation to the least count of measurement.

7.3.1.9. Encoders and their reliability

7.3.1.10. Stage Drives and ways accuracy

7.3.1.11. Film Platen Stability - Expansion, sag, etc.

7.3.2. Film on the Comparator

7.3.2.1. Heat effects of light sources

7.3.2.2. Effect on moisture content of film by vacuum hold down.

7.3.2.3. Emulsion creep or warping

7.3.2.4. Comparison of measurements, emulsion up and down.

7.3.2.5. Comparison of measurements on thin, UTB and Standar Base.

7.3.2.6. Effects of air puck hold down

7.3.3. The Human Being

7.3.3.1. Magnification, resolution, and pointing accuracy.

7.3.3.2. Accuracy of pointing on high contrast and low contract grids as opposed to typical aerial scenes.

7.3.3.3. Degree of accuracy of reticle (dot) superimposition in comparison to electronic correlation.

7.3.3.4. Optimum Measuring Mark Size as per magnification and objects to be measured.

7.3.3.5. Effect of mismatched images in the mensuration process.

7.3.3.6. The effects of image brightness in the binocular eyepieces (balanced vs. unbalanced).

7.3.3.7. Test of various operators in different age groups for depth perception, Y index, fusing dots and imagery.

7.3.4. Error Analysis and Classification

7.3.4.1. Type of errors - systematic, random

7.3.4.2. Frequency - periodic, random, continous

7.3.4.3. Location - Instrument, observer, techniques

7.3.4.4. Cause - recurring erradic

7.3.4.5. Detection - comparison, reappraisal

7.3.4.6. Remedy - Replace or correct

7.3.4.7. Prevention - Education, training, controls

7.4. Tests that might be run

7.4.1. Tests on thin, standard, and UTB in the camera with and without reseau grids.

7.4.2. Flights over known areas with varying but known conditions.

7.4.3. Controlled processing of negs and dupe positives.

7.4.4. Measurement tests on various films and instruments.

7.4.5. Test and Evaluation of stellar comparators, time velocity readers, t-o and four axis comparators.

7.4.6. Evaluation of attitude determination system.

7.4.7. Effect of atmospheric refraction that is other than an average condition.

7.4.8. Test and Evaluation of Comparative measurements and procedures. Vectorial, two axis, four axis.

7.4.8.1. Filar Eyepiece

7.4.8.2. Projected Scale

7.4.8.3. X and Y measuring stages

7.5. Analysis and Experimentation

7.5.1. Prepare graphs, nomograms, etc. to indicate the various errors for camera - film - process - comparator relationships.

7.5.2. Breadboard a vacuum hold down and a high intensity light source. Study the heat effect and the physical conatraint that results.

7.5.3. Prepare computer model that can be used to determine the degree of precision that can be expected for various measuring systems with certain camera/film inputs.

7.5.3.1. High Precision Stereo Comparator, convergent pan camera with thin base negative.

7.5.3.2. Mann Comparator with Standard film and various cameras.

7.5.4. Prepare cost performance curves as per mensuration instruments and encoders vs. accuracy.

7.5.5. Establish calibration methods and techniques for the mensuration instruments presently in use.

7.6. Measurement of Measurements - The types of measuring errors and their interactions in the mensuration process will be investigated.

7.6.1. Fixed Errors

7.6.1.1. Errors in calibration

7.6.1.2. Human errors

7.6.1.3. Errors in technique

7.6.1.4. Experimental errors

7.6.2. Accidental Errors

7.6.2.1. Errors of judgement

7.6.2.2. Variation in conditions

7.6.2.3. Attempt to exceed the precision of measurement system.

7.6.3. Other Errors

7.6.3.1. Mistakes in selection of the instrument or measuring system.

7.6.3.2. Computational errors

7.6.3.3. Chaotic errors - vibration

7.7. The present and planned trend, in photographic bases for aerial reconnaissance systems, appears to be toward thinner based films. The Thin and UTB films are not as dimensionally stable as their predecessors and will, therefore, cause some problems in mensuration. The demand for accuracy of dimensions for technical reporting has increased in the past and is expected to grow ever demanding in the future.

The lack of stability in the Thin and UTB will increase the need for high precision measurements instead of relazing the requirement as might be expected. Very precise measurements will be required over both long distances (20 inches) as well as small distances (less than 1mm) to enable the operator to determine the changes the film and the imagery has undergone in acquisition, processing and exploitation.

7.7.1. Establish correction methods for mensuration readout.

7.7.2. Recommend handling methods, light sources, hold down, etc.

7.7.3. Recommend specifications to be incorporated into future contracts for mensuration equipment.

7.8. The Contractor will be required to develop a computer program(s) for an analytical model(s).

The program(s) will be based on the parameters effecting and contributing to the errors in the mensuration process.

Methods of compensation for dimensional instability will also be developed and a means produced for obtaining correctional values to obtain the required accuracy of measurement.

More specifically, an error analysis will be made for camera, film, processing, and comparator measuring both individually and for any combination. An example might be for UTB exposed in a pan camera, processed as usual, a dupe positive made on Thin Base; and measurements made on a Mann Comparator. The Dimensional changes that will take place, the distortion vector, and the accuracy that could be expected from this combination will be output from the computer program.

8. This project is expected to be a _____ year level of effort.